Alpine fissure as a monitor of hydrothermal activity in exhuming orogens

Tobias Arnold[1], Thomas Pettke[1], Alfons Berger[1], Marco Herwegh[1], Beda Hofmann [1,2]

[1]Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, 3012 Bern, Switzerland
[2]Natural History Museum Bern, Bernastrasse 15, 3005 Bern, Switzerland

Introduction

Alpine fissures form near brittle-to-ductile transition under fluid-assisted embrittlement in exhuming external crystalline massifs. A recently discovered fissure is the Spittellamm-cleft, located at the Grimsel area (Aar-massif). With the samples provided from this site, this study approaches a characterization of the circulating hydrothermal fluids to unravel the evolution of such open cavities in exhuming orogens.

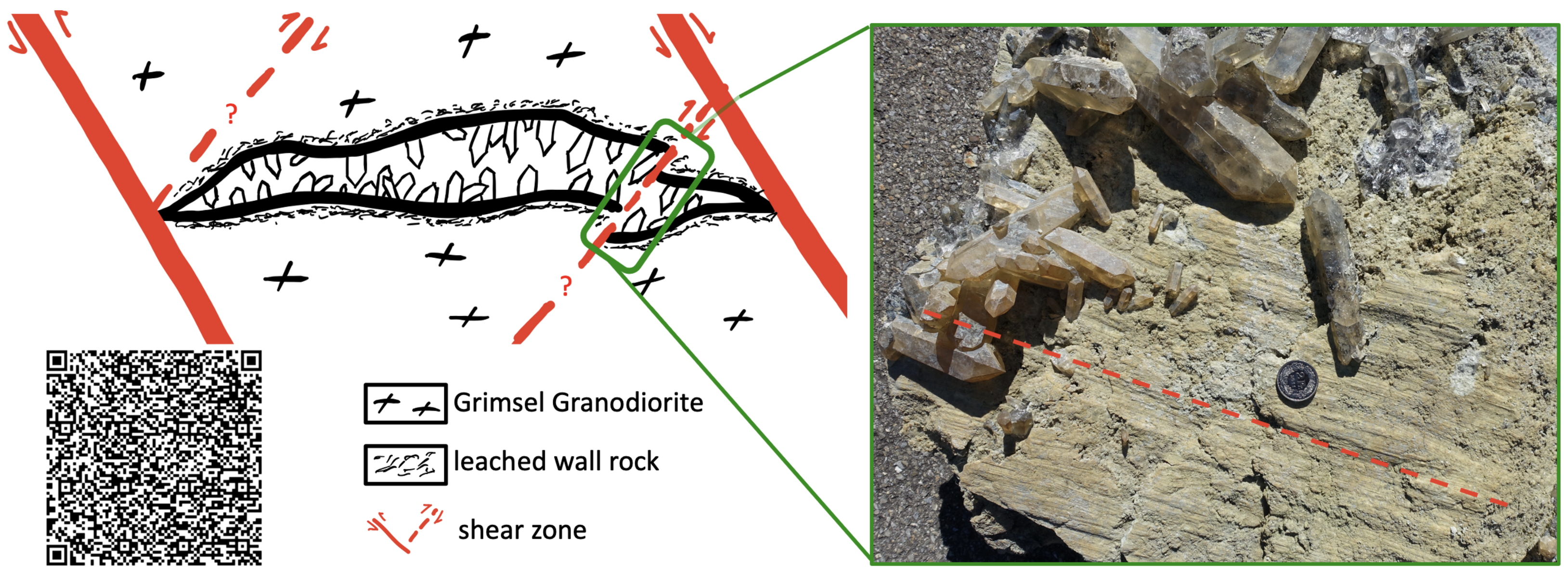

Figure 1: Sketch of an Alpine fissure (cleft): The Spittellamm-cleft hosts quartz crystals overgrowing striations, indicated with the red dotted line on the right image. This has not been reported in Alpine fissures yet. Scan QR-code for location of the site and geological formations.

Results

Petrological observations reveal the crystallization sequence for the Spittellamm-cleft (Figure 2). Two pseudosecondary fluid inclusions assemblages can be distinguished :

	Type 1	Type 2
size range / average size [µm]	5-20 / 15	5 / 5
vapour bubble size [relative]	big	small
average homogenization temperature $T_{h,tot}$ [°C]	220	130
average final melting of ice $T_{m,ice}$ [°C]	-14	-16

Inclusions reaching over 50 µm are conspicuously stretched. Chemical composition characterizes Na-Cl-K fluids. Significant gold signals were measured for nearly all inclusions.

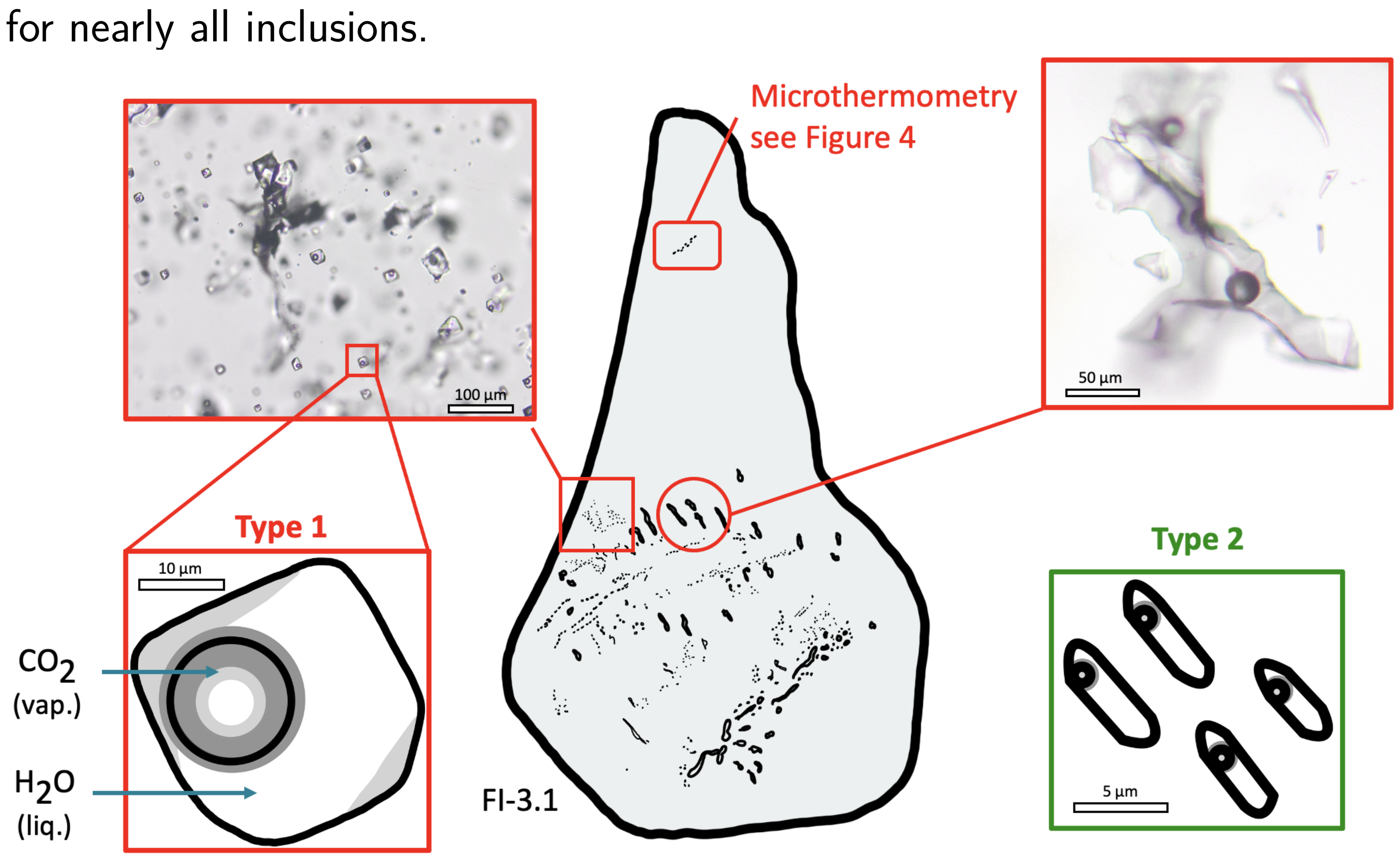

Figure 3: Fluid inclusion assemblages of Type 1 from the sample FI-3: Top right shows stretched inclusions, all dipping in the same direction. Top left shows a cloudy-oriented assemblage. Sketches display two fluid inclusion types. Type 2 is hosted in quartz crystals related to striations, as shown in Figure 1. Top section highlighted in the red box corresponds to the assemblage measured in Figure 4 with highest $T_{h,tot}$ and variable salinity.

Methods

Petrological relationships were studied using a binocular. Fluid inclusions were characterized by optical light microscopy. Microthermometry was measured on a heating-freezing stage calibrated with a synthetic H_2O inclusion standard. Chemical compositions of the fluid inclusions were measured by LA-ICP-MS.

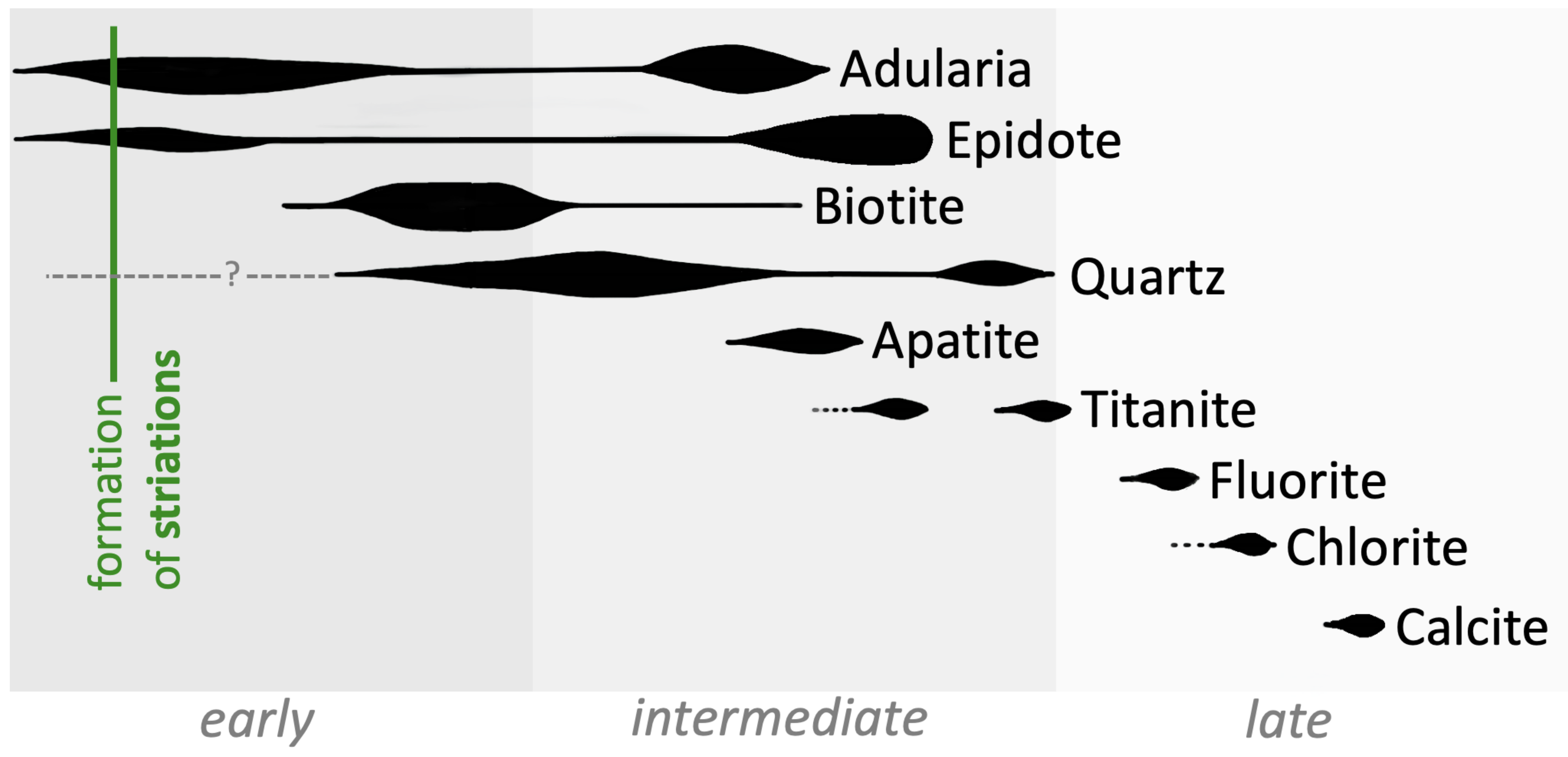

Figure 2: Crystallization sequence based on petrological observations including all the minerals present in the fissure. Thickness of bands correlates with abundances of minerals.

Interpretations

- The metamorphic fluid in Alpine clefts evolves from ~ 450 °C (biotite stability, peak metamorphism) to ~ 130 °C (lowest $T_{h,tot}$) . Such large differences in temperature may indicate hydrothermal activity over long time intervals (Ma?).
- Stretched fluid inclusion assemblages record a reheating event by a significant hotter fluid of minimum 230 °C. Therefore, fluid temperatures in exhuming orogens can vary at local scale.
- Microthermometry supports the hypothesis of different fluid generations (see Figure 4).
- The Spittellamm-cleft shows fluid salinity, which is increasing with decrasing temperature. Na-K-Cl fluids have 0.02 µg/g Au, which is in accordance with [1].
- The opening of Alpine clefts might be linked with seismicity; however, the current data do not allow for testing this hypothesis.
- Alpine clefts are long-lasting, hydrothermally active, discrete structures covering a few 100° C cooling of exhuming orogens.

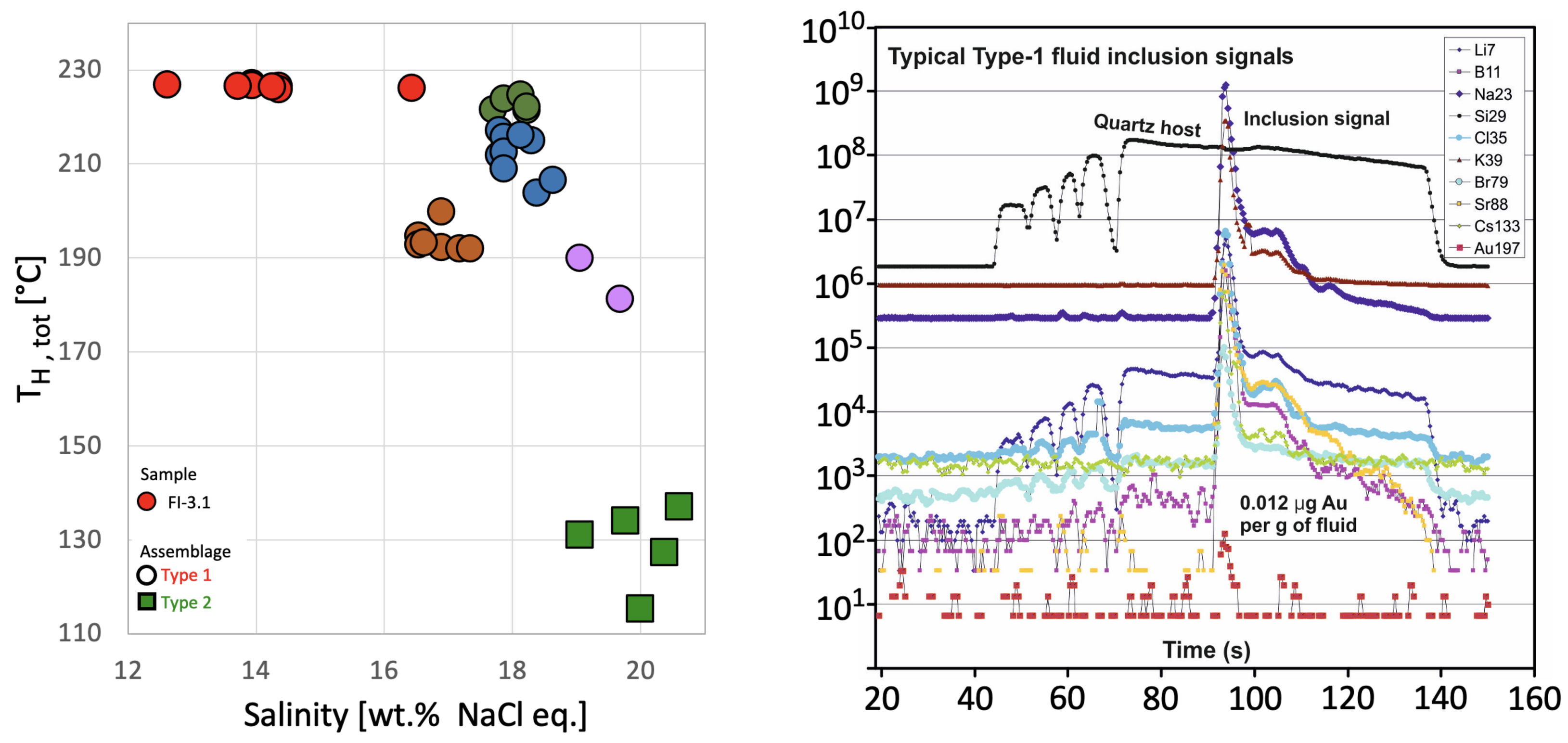

Figure 4: Left: Salinity over $T_{h,tot}$ allows to discriminate two different fluid types. This is in accordance with optical observations in Figure 3. Right: Typical signals for Type 1 fluid inclusions measured by LA-ICP-MS.

Ongoing work

Cl/Br-ratios of fluid inclusions could be used as a tracer of the fluid source. Uncommon hydrothermal biotite in such clefts has the potential for Rb-Sr dating of biotite crystallization and initial Sr isotope ratios may help to constrain fluid source(s) and link mineral growth and deformation.

Aknowledgements & References

The author thanks Martin Wille and Sukalpa Chatterjee for the help with the Rb-Sr isotopic system. The samples for this study are kindly provided by the the Kraftwerk Oberhasli (KWO).

[1] K. Rauchenstein-Martinek, T. Wagner, M. Wälle, and C. Heinrich. Gold concentrations in metamorphic fluids: A LA-ICP-MS study of fluid inclusions from the Alpine orogenic belt. *Chemical Geology*, 2014.